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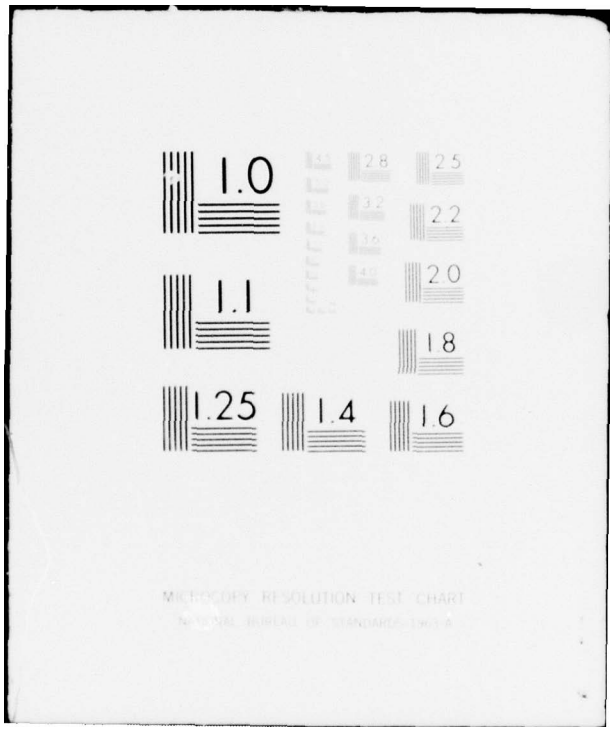
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MONITORING OF THE TRAUMA VICTIM

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FINAL REPORT

William C. Shoemaker, M.D.

July 1973

(For the period 1 February 1969 through 31 July 1973)

Supported by

U.S. ARMY MEDICAL RESEARCH & DEVELOPMENT COMMAND
Washington, D.C. 20314

Contract No. DADA 17-69-C-9089
Mount Sinai School of Medicine
New York, New York 10029

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Monitoring of the Trauma Victim	5. TYPE OF REPORT & PERIOD COVERED: Final (1Feb 69 - 31 Jul 73)
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): William C. Shoemaker, M.D.	8. CONTRACT OR GRANT NUMBER(s): DADA 17-69-C-9089
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Mount Sinai School of Medicine, New York, New York 10029	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62110A, 3A062110A821 00 021
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Medical Research and Development Command, Washington, DC 20314	12. REPORT DATE: July 1973
	13. NUMBER OF PAGES: 20
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

Final rept. 1 Feb 69 - 31 Jul 73,

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cardiac output, O_2 transport variables, O_2 consumption, septic shock, traumatic shock, prediction of outcome, severity of illness, pathophysiology of shock, cardiorespiratory patterns in shock

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A Physiologic patterns of over 20 precisely defined etiologic types of shock were described by over 11,000 sets of sequential cardiorespiratory measurements; each set consisted of up to 35 primary and derived variables. In order to describe the natural histories of each shock syndrome, ~~we used~~ were used only cardiorespiratory data obtained remote from therapy, i.e., before therapy was started or after the immediate, direct cardiovascular effects of the therapy were spent. The underlying common denominator in each

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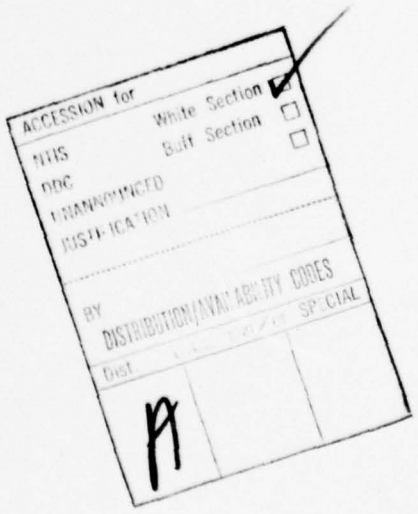
20. Abstract (continued)

of these shock syndromes was decreased O_2 consumption ($\dot{V}O_2$) in the early hypotensive period; this often occurred before the patient was recognized to be in shock. Thus, the lesion in shock is not just low flow, but more often, as in septic and traumatic shock, it is uneven flow; i.e., maldistributed flow with inadequate tissue oxygenation manifest by reduced $\dot{V}O_2$.

Secondly, with this data base, we showed distinct differences in the physiologic patterns of survivors and nonsurvivors of life-threatening trauma despite a wide variety of traumatic disorders.

Thirdly, we developed a method for prediction of survival after life-threatening trauma and surgical operations. This predictor, which is derived from all available monitored data, was highly statistically significant even in the early stages before the patient was recognized to be in shock. It is also used as an index of severity to quantify progressive changes produced in time and/or therapeutic interventions.

Fourthly, when each therapeutic intervention was made one-at-a-time, single file, with cardiorespiratory measurements before, during, and after each therapy, it is possible to: (a) evaluate quantitatively the relative efficacy of various therapeutic agents, (b) characterize more completely the precise indications and contraindications for each of the common therapies by physiologic criteria relative to survival, (c) define optimal goals of therapy in physiologic terms as these may be quite different from the normal values of unstressed subjects, (d) develop an automatic system for titration of therapy to predetermined physiologic goals as a means of reducing mortality and morbidity. With the improvements in the State of the Art of data acquisition systems (Swan-Ganz thermodilution cardiac outputs) and with present commercially available monitoring systems, these goals can be accomplished for use at the bedside.



FINAL REPORT

United States Army Contract No. DA17-69-C9089

1 February, 1969 to 31 July, 1973

Studies supported over the past four and one half years by Unites States Army contract number DA 17-69-C9089 have led to 68 publications in basic and clinical investigations in shock and trauma.

The basic problem in shock and trauma states was approached by describing the physiologic patterns in septic shock by sequential cardiorespiratory measurements taken remote from therapy. We found that there was essentially two different types of septic shock, "pure" uncomplicated sepsis (not associated with trauma, blood loss, etc.) and the complicated septic shock which frequently follows trauma and hypovolemia. We found that common to both groups was a normal or high cardiac output (unless limited by hypovolemia or myocardial functional impairment) and inadequate oxygen transport. The basic lesson therefore was not low flow, but maldistribution of flow such as to result in inadequate oxygen transport.

A second major effort was to analyze the therapeutic approaches to this problem. Preliminarily, we reviewed the effects of various agents in clinical shock states, but we found that identification of the physiologic defect and cataloging the actions of each available therapeutic agent was useful but not entirely adequate because, as it became evident, the values of normal unstressed man were not optimal for the patient in shock. We, therefore, attempted to define the "optimal" values for shock patients by description of the physiologic pattern of survivors and non-survivors. The values of survivors were assumed to be a first approximation to optimal values and therefore, represented the proper physiologic goals of therapy, while the values of non-survivors would serve as early warning of impending disaster. We have completed this retrospective study on 98 cases of traumatic shock and plan to develop a prospective study. We have also analyzed the data of this study by a nonparametric multivariate analysis to develop predictors that will classify the patients as a survivor or nonsurvivor. We have also used the frequency of the positive predictors as a means to assess the significance of each of these physiologic changes.

Cardiovascular alterations in complicated and uncomplicated septic shock

Early in our studies we noted marked differences in hemodynamic and metabolic events occurring with time and with various types of sepsis. It occurred to us that there were really at least two, quite different, types of septic shock: "pure", uncomplicated sepsis and the more commonly encountered type of sepsis seen in the postoperative patient with complications.

Over a five year period, we accumulated a series of 18 patients with uncomplicated septic shock; about half of these patients had septic abortions. The hemodynamic pattern which characterizes the early or "B" stage of uncomplicated septic shock consists of increased cardiac output and heart rate, decreased arterial pressure, peripheral resistance, stroke index, left ventricular stroke work, and cardiac work as well as relatively normal venous pressure, mean transit time and central blood volume. This hemodynamic pattern permits identification of several possible physiologic mechanisms which are operative in the development of this syndrome (Ref. 1,2).

Increased cardiac output in the B, C_2 and D stages was accompanied by alkalosis and reduced pCO_2 values in all of the patients of this uncomplicated septic shock series (Ref. 1). By contrast, the low cardiac output of hemorrhagic shock was frequently associated with hypercarbia, acidosis, lactic acidemia and base deficits. Respiratory alkalosis reduced cardiac output and hypercarbia increased it, but metabolic factors other than pH and CO_2 may also play a role in the development of the septic hemodynamic patterns. Dubois has shown that hyperthermia and increased body metabolism is associated with increased cardiac output; the latter increased 7% per degree F elevation of body temperature. However, in most of the present cases, the observed increase in cardiac index was greater than that which could be accounted for by Dubois' data. This is interpreted to mean that the physiologic needs of critically ill patients for blood flow and oxygen may be greater than that predicted from data obtained in hyperthermic men who are otherwise normal.

Pulmonary venous admixture and respiratory insufficiency as reflected by arterial desaturation and "shunt" calculations occur in the middle and late stage of septic shock and, are probably not involved in the genesis of the syndrome. However, these pulmonary factors may contribute to the relatively late hemodynamic patterns and they may be

important mechanisms of death as well as stimuli to increase cardiac output; i.e., cardiac output may increase in compensation for reduced pulmonary function.

General supportive measures should provide optimal circulatory function relative to the particular needs of the patient and not necessarily restoration of normal values. Thus, in this series upon finding reduced blood volume, blood flow, and oxygen consumption, vigorous volume therapy was given with whole blood transfusions, plasma, and plasma expanders. When blood volume, cardiac output, and oxygen consumption were found to be near normal values, additional colloids also were given on the assumption that the optimal blood volume should be approximately 1 liter greater than the predicted normal values and that additional blood flow and oxygen are needed. Nevertheless, volume loading was not pressed beyond a central venous pressure of 12 to 13 centimeters of saline solution.

All but one patient with low cardiac output in the early stages responded to volume loading. Almost all of those with normal or high cardiac output also responded by increased flow to volume loading, isoproterenol, or a combination of both. Occasionally, in the terminal and preterminal stages, low cardiac output occurred in the presence of increased venous pressures; in those instances, we frequently resorted to administration of digitalis and sympathomimetic agents, usually norepinephrine or metaraminol. Peripheral resistance was usually found to be low, an indication that blocking agents were not required. We did not find significantly improved flow after the administration of blocking agents, but these agents did increase the tolerance to administration of additional fluid (Ref. 1,2).

Five patients in the present series died as a result of shock; all of these were first seen in the terminal or preterminal stage of the shock state. Another three patients survived shock but died during their subsequent hospital stay, primarily of complications associated with subsequent operative procedures. Ten patients survived and left the hospital apparently well and healthy. Thus, the over-all hospital mortality rate was 44 per cent, and the mortality rate of the septic shock itself was 28 per cent. Presumably, if the patients seen by us in the late stage of shock had been treated aggressively in the early stages, the survival rate may have been improved. Other investigators have reported 40 to 80 per cent mortality rates; these statistics have remained unchanged even in recent years (Ref. 1,2).

Similarly, we studied a series of 57 shock patients who also had trauma and blood

loss. The physiologic alterations were analyzed and compared with those of the uncomplicated septic shock series.

In the early period, hypotension, tachycardia, normal or elevated cardiac output, normal or reduced peripheral resistance, low stroke volume, low stroke work, low A-V oxygen difference and low oxygen consumption occurred in both groups. But patients with complicated sepsis had greater reductions in oxygen consumption in the early stage and greater increases in the late stage even though they had lesser degrees of shock as measured by the hypotension.

The data suggest that the bulk movement of blood (indicated by the cardiac output) as well as the functional capacity of the circulatory system to deliver oxygen to the tissues (indicated by oxygen consumption) rather than the degree of hypotension, is the major determinant of survival.

The rate of oxygen consumption may be considered an essential overall index of the total body metabolism which reflects the sum of all oxidative metabolic processes, and, thus, the general state of body metabolism. As such it may be extremely useful both for minute-to-minute monitoring of the patient's physiologic status and for evaluation of the effectiveness of therapy. This measurement is advantageous because oxygen cannot be stored, and, except within narrow limits, appreciable oxygen debts cannot be accumulated for long periods of time. Therefore, the rate of oxygen uptake very nearly approximates the rate of oxygen transport which approximates the rate of oxygen consumption.

If oxygen consumption is the central factor that regulates the circulation, then this factor would be expected to be more stable than other hemodynamic and metabolic variables. This is because small deviations in the regulating factor would stimulate hemodynamic and metabolic changes that would tend to return the regulating factor toward normal. Thus, the compensatory reactions may vary widely in response to lesser changes in the regulating factor. However, as deterioration develops, the regulatory mechanism itself may also be affected. Oxygen consumption has many of the characteristics of a regulating mechanism; but if it is not the physiologic regulator, it is probably closely related. Tentatively, we may treat it as though it were the regulator to develop hypotheses preparatory to more definitive analysis of circulatory dynamics and its governance.

Although patients with uncomplicated sepsis seen in the early stages of septic shock had an average mortality of 22%, but complicated septic shoch patients had higher mortalities depending on associated clinical factors such as the surgical complications, fistulae, renal failure, etc. Thus, the body may overcome greater degrees of hypotension from sepsis which is not complicated by trauma and blood loss easier than it can survive lesser degrees of hypotension of the septic shock which follows hard upon trauma and hemorrhage. In essence, the complicated septic shock patients had greater distortions of cardiorespiratory patterns relative to the degree of hypotension and this was associated with greater mortality.

Hemodynamic changes in pericardial tamponade from penetrating chest injuries.

We studied a series of 80 patients who had penetrating cardiac wounds with hemopercardium after knife or gunshot wounds and monitored the sequence of hemodynamic events and the responses to therapy in 13 of these patients (Ref. 5). This group represents a small subset of cardiogenic shock. The primary hemodynamic mechanism of tamponade is generally attributed to increased intrapericardial pressure and volume displacement of the chambers of the heart; this decreases the effective filling pressure of the ventricle and thereby reduces stroke volume. Low stroke indices, which were observed in 82% of the patients, give rise to several compensatory hemodynamic reactions: increased heart rate tends to maintain cardiac output in the face of reduced stroke volume; increased central venous pressure tends to increase right ventricular filling; and vasoconstriction, reflected by increased peripheral resistance, tends to maintain arterial pressure when cardiac output falls. The onset of decompensation is suggested by falling central venous pressure associated with hypotension and low cardiac output. Using an experimental animal preparation with chronic indwelling catheters in the pericardial sac and in various intravascular sites, sequential cardiovascular measurements were made under unanesthetized conditions as blood was instilled into the pericardium. Progressive decreased in stroke volume and cardiac output occurred with the appearance of physiologic compensations. Cardiac arrest and death occurred as pulmonary arterial-left atrial pressures approached zero; at this point, forward flow of blood across the

lesser circulation ceased. Definitive therapy consisted of removal of the hemopericardial fluid or clots. Since a high percentage of clots were found (65%), which were associated with false negative pericardiocentesis (19%), and since active bleeding from the lacerated cardiac chambers could not always be ruled out, surgical intervention usually was undertaken. Conservative or preoperative therapy, consisting of pericardiocentesis, volume loading and isoproterenol infusions, were shown to improve the cardiovascular status. Volume loading with plasma expanders, which increased central venous pressure and venous return to the right heart, augmented the compensatory responses. Isoproterenol, when used judiciously, improved myocardial contractility and thereby increased stroke volume and cardiac index. Pericardiocentesis improved stroke volume and cardiac index. Each of these were useful in correcting specific aspects of the disorder during resuscitation as well as in preparing the patient for operation; each also had distinct limitations (Ref. 5).

Clinical and experimental studies of cardiovascular alterations in acute cerebral injury

Systemic hypertension with bradycardia as well as systemic hypotension, which is not explicable in terms of volume deficit or sepsis have been recognized in patients with acute craniocerebral trauma. However, hemodynamic changes in this type of patient have not been previously reported. Observations in eight patients with acute cerebral injury revealed hemodynamic patterns and drug responses which differ from both the normal subject and patients with other types of acute injury. In particular, we have observed a pattern of ventricular insufficiency (or failure), suggested by reduced left ventricular stroke work at normal and high inflow pressures, early in the time course of cerebral trauma; this was reversed by exogenous catechol amine or by isoproterenol administration. The reduced ventricular function was not apparent three days after injury. Absence of atropine-induced tachycardiac and baroreceptor-mediated bradycardia also were observed in patients with acute head injuries.

The possibility that some of these changes might be due to decreased cerebral blood flow prompted the development of an experimental canine preparation in which cerebral blood pressure could be maintained at levels lower than systemic pressure

over prolonged periods of time. Initial results indicate a progressive diminution in cardiac output during cerebral ischemia. Cardiac output may be increased or further decreased by restoration of normal cerebral perfusion pressure at different points in the time course of cerebral ischemia. Elevations of systemic pressure during cerebral ischemia with catechol amine produced a response similar to that observed in patients with acute cerebral injury; i.e., absence of reflexly mediated bradycardia (Ref. 9).

We also observed sequential hemodynamic events in a group of patients with head injury throughout their clinical course. Significant hemodynamic changes in the series as a whole were low cardiac output and stroke volume during the early period and return to normal or above during the middle and late periods; these was an initial tachycardia which decreased during successive stages. In the early period, the patients who did not survive had lower cardiac output, higher peripheral resistance, lower central blood volume, lower stroke volume and lower stroke work than did the survivors. During the middle and late periods, the nonsurviving patients had cardiac outputs, stroke volumes and heart rates similar to those of the survivors.

These observations suggest that therapy of patients with head injury should include sympathomimetic agents to maintain cardiac output before hypotension occurs (Ref. 5).

Use of Sequential Cardiorespiratory Variables as Predictors of Survival, for Definition of Therapeutic Goals, and for Early Warning of Death

Cardiorespiratory patterns were described by sequential physiologic measurements obtained during times remote from therapy in 98 patients before and after extensive surgical trauma. Early (stages B and low), middle (stages C_1 and C_2) and late (stages D, E and F) periods were defined by time and arterial pressure criteria so that data could be analyzed at comparable periods. There were distinct differences in the cardiorespiratory patterns of 67 surviving patients as contrasted to the 31 who subsequently died. In the early period, the nonsurvivors had lower cardiac output, higher mean transit time, low stroke work and stroke volume, higher pulmonary vascular resistance, reduced oxygen availability, reduced oxygen

consumption, acidosis, higher pCO_2, and greater reductions in hematocrit and blood volume as compared with their own controls. Goals of therapy are not necessarily to maintain normal values, since compensatory reactions (such as tachycardia) present departures from the normal. Therefore, therapeutic goals are to achieve optimal physiological interrelationships which lead to survival. The cardiorespiratory pattern of the survivors represents a reasonable first approximation to the optimal pressure, flow, volume and oxygen transport relationships. Specific physiologic criteria for therapeutic goals are proposed, based on these data. Furthermore, specific criteria which may warn of impending disaster are proposed based on the early cardiorespiratory patterns of patients who subsequently died. Their presence suggests that active therapy should be directed toward producing the physiologic pattern of the survivors (Ref. 47).

The data were also analyzed retrospectively by a nonparametric multivariate analysis; in this approach, the ranges of each available cardiorespiratory variable at each stage of 67 survivors were compared with those of 31 patients who died. A high percentage of patients who died in shock were classified in the early and late period, and a high percentage of surviving patients were classified in the late stage; 94% of the survivors and 89% of the entire series were identified by one or more positive variables, while 87% and 80%, respectively, were classified by two or more variables. Those variables which were most useful as predictors in the early period, were, in order of frequency: oxygen availability, pCO_2, pulmonary vascular resistance, pH, oxygen consumption and extraction ratio, hemoglobin, right and left stroke work and cardiac work, and pulmonary arterial pressure. Pulmonary hemodynamic changes were most commonly affected in the early period of non-survivors (Ref. 66).

As a first approximation to evaluation of the frequency of the mechanisms involved, the cardiorespiratory variables were grouped according to their most likely underlying physiologic problem. In the early period, the most frequently positive variables were, in order of frequency, acid-base and oxygen transport problems, neurohumeral influences (including both systemic and pulmonary vascular resistance), cardiac factors and blood volume-related variables. It is concluded that this type of approach may help to elucidate underlying physiologic mechanisms and that prospective studies may lead to development of more precisely defined physiologic criteria for therapy (Ref. 66).

Experimental and Clinical Studies on Pulmonary Hemodynamics and Lung Function in Shock States

Death from pulmonary failure in clinical shock is largely due to alterations in pulmonary venous admixture with ventilation-perfusion ($\dot{V}/\dot{Q}$) abnormalities which are related to very early increases in pulmonary vascular resistance; the latter was found to be an important early predictor of survival.

Sequential hemodynamic, oxygen transport and pulmonary venous admixture measurements were performed in experimental animals as well as in shock patients remote from therapy. In surviving patients, the early physiologic response consisted of hypotention, increased PVR, normal arterial pH, and normal central blood volume. There was an increased cardiac output with normovolemia and usually decreased cardiac output in the presence of hypovolemia. During the early period of shock, the nonsurvivors had lower cardiac output, higher central blood volume, higher PVR, greater acidosis, and lower oxygen consumption.

Increased PVR occurred early, often before development of maximal hypotension and low cardiac output in both clinical and experimental conditions. The magnitude of the PVR increase was roughly related to the extent of the trauma and hemorrhage; the increase was significantly greater in nonsurvivors. The increased PVR was associated with acidosis during hypovolemia, increased central blood volume after volume deficits were restored, and with the subsequent appearance of pulmonary shunting (Ref. 66).

Pulmonary hemodynamics, respiratory function, and the distribution of pulmonary blood flow was studied in seven unanesthetized dogs, without previous thoracotomy, using a previously described protocol of hemorrhage designed to stimulate clinical shock. A method was first devised to measure the distribution of pulmonary blood flow serially in unanesthetized dogs using 5 different radioactive isotope labelled microspheres (Ref. 15). The labelled microspheres were injected sequentially in a control period, immediately after hemorrhage, at various stages after hemorrhage and retransfusion to evaluate the blood flow to six vertical segments of lung (Ref. 15). Pulmonary blood flow was evenly distributed in the control period. Following hemorrhage, there was a

decrease in pulmonary artery and left atrial pressure with an increase in blood flow to the dependent areas relative to the upper areas. This was associated with decreased pCO_2 values and increased in pO_2, minute volume, respiratory rate, pulmonary dead space, and pulmonary vascular resistance (P/Q). There was a marked base deficit but only a small decrease in pH due to compensating respiratory alkalosis. By the end of the hypovolemic period, there was a redistribution of blood flow upwards against the hydrostatic pressure: this became more pronounced after reinfusion of the shed blood. After reinfusion, a slightly increased pulmonary shunt occurred which did not contribute significantly to the increased cardiac output. The pH fall seen was due to the reversal of hyperventilation and an increase in pCO_2. Pulmonary vascular resistance remained elevated after the pH returned to normal. Metabolic acidosis was cleared very slowly despite the return to normal. Metabolic acidosis was cleared very slowly despite the return of cardiac output and an increase in oxygen consumption. These findings suggest that subtle alterations in pulmonary hemodynamics and blood flow distribution after hemorrhage occur prior to the development of arterial oxygen desaturation. These changes in pulmonary flow distribution initially may be compensations for structural alterations of pulmonary capillary beds and they may in part be produced by neurohumoral mechanisms having protective value.

In order to elucidate regulatory mechanisms underlying the pulmonary hemodynamic response, we studied sequential changes in PVR prolonged hemorrhagic shock in 18 conscious dogs (Ref. 65). In eight, the mixed venous pH was maintained within normal range by infusing sodium bicarbonate; in ten control dogs the pHv was not treated. Severe metabolic acidosis in the untreated group was associated with an average increase in PVR of about 300 percent. But when the pHv was controlled, the PVR was increased only about 100 percent. Forth percent of the untreated dogs were found to have appreciable gross lung pathology; these dogs previously had marked and persistently increased PVR during the antecedent hypovolemic shock stage and subsequently increased pulmonary venous admixture in the postshock period. By contrast, none of the treated dogs had appreciable amounts of increased pulmonary venous admixture or appreciable amounts of gross lung pathology. It was concluded that severe metabolic acidosis is responsible for the major part of the increased PVR and that prolonged increases in PVR during

hypovolemic shock period is associated with the development of shock lung during the postshock period (Ref. 17, 65).

These data indicate that trauma, hemorrhage and other forms of stress produce pulmonary vasoconstriction from neural influences; initially at least, this is a compensatory mechanism which tends to redistribute blood flow upward. However, the increased PVR may be exaggerated by metabolic, hormonal, and rheological factors. The persistence of a high PVR leads to the backup of blood behind the lesser circulation and uneven blood flow in the microcirculation. Thus, ventilation-perfusion abnormalities are produced by maldistributions of regional or zonal pulmonary blood flow as well as maldistributions of flow at the microcirculatory level (Ref. 66).

The observed patterns of these variables have therapeutic implications. An emphasis on improved ventilatory function is appropriate but limited because the perfusion half of the $\dot{V}/\dot{Q}$ equation is also of major importance. Increased blood flow and reduced PVR may be accomplished by: 1) correction of acidosis; 2) volume loading with plasma expanders such as albumin, dextran-40 and blood; and with 3) high-doses of steriods; and 4) inotropic agents (Ref. 66).

We have evaluated the effects of various agents on PVR in over 200 instances in patients with postoperative and posttraumatic shock. After two to six control PVR measurements, an infusion of an agent is made and PVR measurements repeated at frequent intervals during and after infusion. We observed pronounced reductions in PVR following infusions of methylprednisolone (30 mg/kg over a 5 to 10 minute period) and of 500 ml of a volume expander over a 60-minute period. There were no significant changes following infusions of saline or Ringer's lactate solution. The mean PVR responses to the various agents are summarized in Table 1.

Table 1
EFFECTS OF VARIOUS AGENTS ON PERIPHERAL VASCULAR RESISTANCE (PVR)

	Mean values in dyne · $sec^2/cm^5 \cdot M^2$ ± standard error		
	Control	During Infusion	After Infusion
Whole Blood	344±23	32±24	313±20*
Albumin	285±27	251±25	241±26*
Dextran-40	290±25	258±26*	237±27*
Saline/Ringers Lactate	329±45	314±26*	339±32
Methylprednisolone	354±38		247±41*

*Statistically significant at the 5% level of confidence using the t test for paired distributions.

Sympathomimetic agents (i.e., norepinephrine, metaraminol), excess sodium, overhydration, and dishydration should be avoided in the presence of increased PVR. Vigorous programs for changing position-turning the patient from side-to-side every two hours, as well as more extreme changes in position-may also be indicated to improve perfusion as well as postural drainage (Ref. 66).

The relevance of nutritional problems in acute post-traumatic states; the effects of hypertonic glucose and glucagon in therapy of shock

To test the hypothesis that inadequate energy substrates may be important to nutritional and metabolic failure in critically ill patients, we measured hemodynamic and oxygen transport effects of glucose, 1 gram/kg body weight, given intravenously over a 30 minute period in a series of acutely ill patients. The responses of patients who had been maintained on the standard clinical fluid regimen of 5% glucose were compared with those given 2000 calories per day by intravenous administration of hypertonic glucose. The glucose load produced a marked improvement in hemodynamic and oxygen transport variables in the patient group maintained on 5% glucose; patients who caloric needs were maintained with 50% glucose did not show significant changes. The findings suggest that insufficient nutrition may contribute to cardiorespiratory deterioration in the acutely ill patient and that these physiologic variables are improved by administration of adequate energy substrates in the form of hypertonic glucose (Ref. 57).

The effect of glucagon on hemodynamic and oxygen transport was studied in 11 severely stressed post-traumatic patients. When these responses were evaluated in relation to the patients prior intravenous therapy, those patients who had received increased metabolic substrate (50% glucose) had greater and more consistent responses to glucagon infusion. This indicates exogenous glucose supplies the metabolic substrates necessary for the inotropic effect of glucagon. It is also suggested that the variability in response observed clinically with this hormone may be related to the carbohydrate availability. Since critically ill patients are frequently undernourished or depleted by the traumatic episode, the therapeutic use of glucagon should be accompanied by adequate caloric intake (Ref. 58).

Our experience in providing adequate intravenous feeding during the past decade, which emphasized nutritional aspects of acute critically ill and shock patients, was recently reviewed in a basic science publication (Ref. 65).

Publications supported by U.S. Army Contract No. DA-C-9089

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